were softer and riper than fruit in middle layers (table 2). This difference was particularly noticeable in the first shipment to Hong Kong (table 2). Top layer temperatures were higher during transit on this test than on subsequent tests.

CONCLUSIONS

Temperature was the overriding factor affecting decay and ripening of strawberries during transit. Handling and shipping procedures that help retain the initial low temperature achieved by precooling should be used whenever possible. These tests showed that a closed airline container, such as the LD–3 or LD–7, helped to slow warming of the fruit. Placing dry ice on top of the pallet also slowed warming of the fruit, especially in top layers. When used in combination with a closed container, dry ice should provide the most protection; however, adequate insulation to prevent freezing must be provided.

High CO_2 atmospheres retarded the development of decay; however, because the films used for pallet covers failed a number of times, a stronger film should be used to insure a tight seal that would retain the CO_2 atmosphere.

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U.S. GOVERNMENT PRINTING OFFICE: 1976 O—597-790

QUALITY MAINTENANCE OF CALIFORNIA STRAWBERRIES EXPORTED TO FAR EASTERN MARKETS

Marketing Research Report No. 1053

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENTS

The cooperation and assistance of the following are gratefully acknowledged:

Driscoll Associates, Watsonville, Calif.
Paramount Exports, San Francisco, Calif.
Tokyo Seika Co., Ltd., Tokyo, Japan
ETAK International, Ltd., Hong Kong
Pan American Airlines
Northwest Orient Airlines

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Washington, D.C. Issued May 1976

QUALITY MAINTENANCE OF CALIFORNIA STRAWBERRIES EXPORTED TO FAR EASTERN MARKETS

By C. MAX HARRIS, *plant physiologist,* and JOHN M. HARVEY, *research leader, Agricultural Research Service, Western Region, Fresno, Calif.*

SUMMARY

Transit times for air shipments of strawberries sent from shipping points in California to wholesale markets in Tokyo and Hong Kong averaged 28 and 37 hours, respectively. These times may vary, however, because of differences in schedules among various airlines serving these areas.

Pallet loads of fruit remained cooler during transit when shipped in enclosed airline containers than when shipped on open, netted master pallets. Warming of berries in the top layers was slowed by the use of dry ice and plastic film pallet covers. The covers also provided a gas barrier around the fruit that retained carbon dioxide atmospheres, which retard development of decay.

INTRODUCTION

Shipments of California strawberries to the Far East have increased dramatically in recent years. In 1972, according to Market News Service reports, about 11,000 pounds of strawberries were shipped to Japan; in 1973 and 1974, the totals reported were 140,000 and 2 million pounds, respectively. Figures are not readily available on the volume of berry shipments to Hong Kong because strawberries are usually listed with other perishables under "Mixed loads of produce," but indications are that berry shipments are increasing to this city. As the demand for strawberries in the Far East has increased, the shipping season has been extended to include summer months when temperature and humidity are high at both shipping point and destination cities. Because of these adverse conditions and the prolonged marketing time required, it is important that every precaution be taken to protect this highly perishable crop during transit.

All strawberries exported to Far Eastern markets are shipped by airfreight. No refrigeration is available for the berries during air transit, and berries are not usually refrigerated at airports. Because of these conditions, fruit temperatures are much higher than the optimum (32° F) during most of the transit period (*6, 7, 8, 9, 10*).[1]

Modified atmospheres high in carbon dioxide (CO_2) partially comp
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[1] Italic numbers in paren
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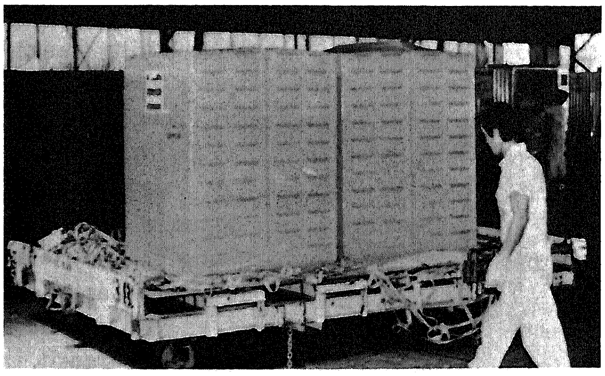
METHODS

Three test shipments were exported to the Far East in May, July, and August of 1974. The first two shipments were destined for Hong Kong and the third for the Tokyo market.

All test shipments originated in Watsonville, Calif., where strawberries were obtained from nearby fields and brought to a central precooling and shipping plant. Test crates of berries were selected at this point for uniformity of quality, maturity, and growing location. These test crates, along with empty crates containing recording thermometers, were placed in the top and middle layers of each test pallet of berries.

After the pallets were assembled, the fruit was precooled to about 35° F in a "forced air" cooler (*3*) on the afternoon of the day of harvest and shipped the same night or the following morning.

All test pallets were covered with a polyethylene, heat shrinkable plastic bag after cooling. The bags, when heat sealed to a sheet of plastic film that had been placed under the crates prior to palletization, make an almost airtight enclosure around each pallet of berries (fig. 1). Dry ice was placed inside this enclosure in some pallets to create a high CO_2 atmosphere around the berries and to provide additional cooling during transit. The dry ice (4 to 6 pounds) was wrapped in heavy paper and placed on top of the pallet before covering it with the plastic bag. A 1-inch sheet of polystyrene insulation was placed under the dry ice to prevent freezing damage to the fruit. A commercial system that provides high CO_2 atmosphere by directly inserting the gas into the bag also was tested. Atmosphere composition



PN-4406

FIGURE 1.—Pallet loads of strawberries on an airline master pallet during unloading at Tokyo airport.

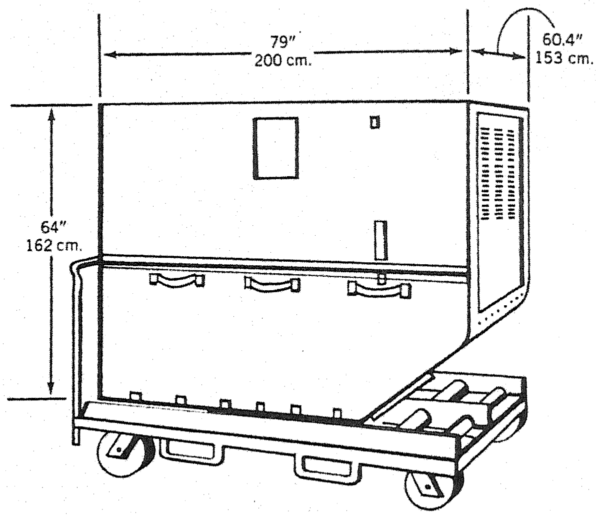


FIGURE 2.—Aluminum airline container (LD–3), which holds one pallet of strawberries.

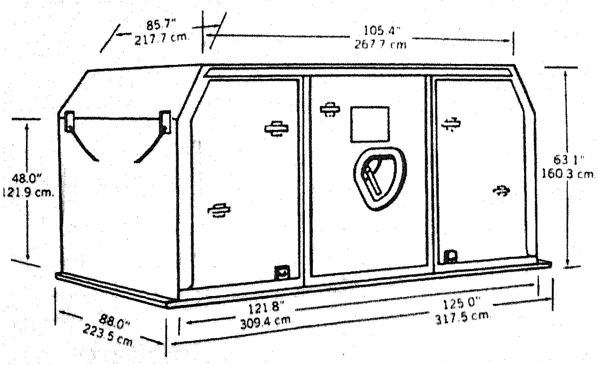


FIGURE 3.—Airline container (LD–7), which holds six pallets of strawberries.

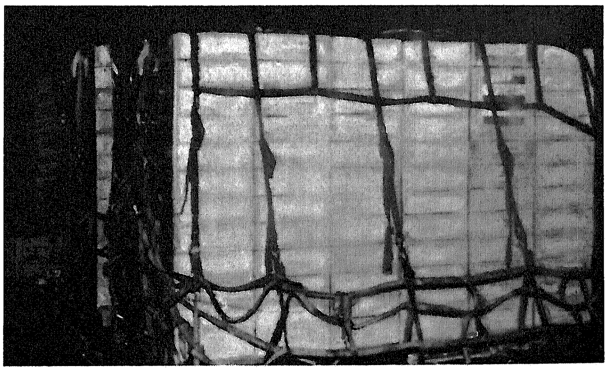


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FIGURE 4.—Strawberries loaded on an airline master pallet and secured by nylon netting.

within the test pallets was measured with an Orsat-type gas analyzer. Measurements were made at shipping point, at the airport before departure, and on arrival at the destination airport.

The strawberries were transported in refrigerated trucks from the precooling plant to the San Francisco airport where they were placed on airline master pallets or in aluminum or fiberglass containers, which hold from one to six strawberry pallets (figs. 1, 2, and 3). On master pallets, the berries were secured by a nylon netting, which fits over the load and attaches to the edges of the pallet (fig. 4).

Test packages of strawberries and recording instruments were removed from the pallets at the airport (Hong Kong) or at the wholesale market (Tokyo). Quality evaluations were made as soon as possible after recovery, and sound fruit was returned to the receiver.

RESULTS

Time in Transit

Total transit time from shipping point to arrival in Hong Kong was about 37 hours (figs. 5 and 6). Stopovers on these flights occurred at Honolulu and Tokyo, and both shipments spent an additional 12 hours at the airport in Hong Kong. Because they arrived late at night, the strawberries were held in a warehouse overnight and were delivered on the following morning.

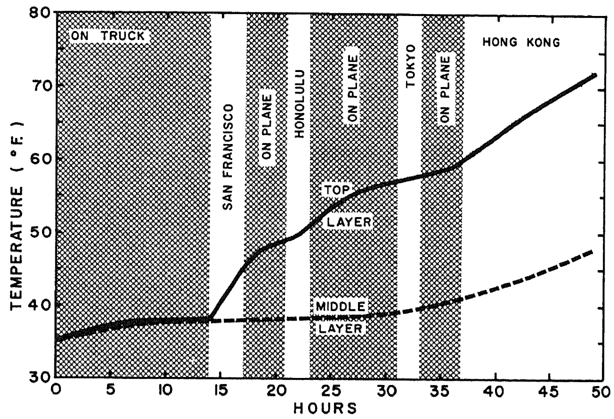


FIGURE 5.—Strawberry shipment to Hong Kong, May 21, 1974.

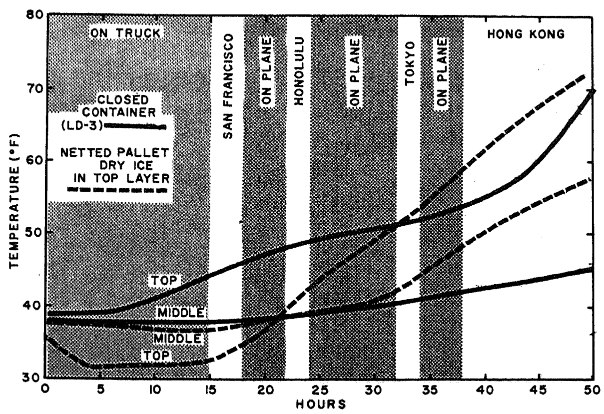
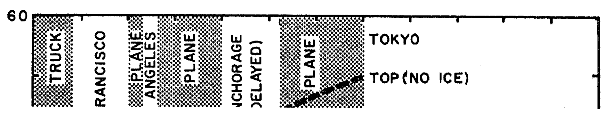


FIGURE 6.—Strawberry shipment to Hong Kong, July 9, 1974.

Total transit time for the test shipment to Tokyo was 28 hours (fig. 7). The flight made stops in Los Angeles and Anchorage (for refueling). There was an unscheduled delay of approximately 4 hours at Anchorage on this flight. Total transit times to either Tokyo or Hong Kong may vary due to differences in schedules and the number and location of stopovers among various airlines serving these areas.

Temperatures in Transit

Pallet loads of strawberries tend to accumulate heat in the upper part of the stacks after they are removed from refrigeration. Consequently,



fruit in the top layers warmed up much faster than fruit in the middle layers, except in the pallets in which dry ice was used. In the first test (fig. 5), top and middle layer temperatures were the same while the fruit was held in the refrigerated truck, but at the San Francisco airport, where the berries were exposed to high ambient temperatures, top layers began to warm at a much faster rate than middle layers. On arrival in Hong Kong, fruit in the top layers averaged 60° F whereas that in the middle layers averaged 41° (fig. 5). When the berries were delivered, the top layer temperatures had increased to 73° and the middle to 47°.

In the second test shipment sent to Hong Kong, the strawberry pallets were transported in different types of airline containers. A pallet with dry ice was carried on an open, netted airline pallet, and a pallet without dry ice was carried in an enclosed aluminum container. Fruit temperatures were initially lowered in the pallet with dry ice, but rose at a much higher rate when shipped on an open pallet than temperatures in the pallet without dry ice shipped in the aluminum container (fig. 6). Upon departure from San Francisco, fruit temperature in the top layer was 34° F in the pallet with dry ice, and 46° in the pallet without ice (fig. 6). At the stopover in Tokyo, both temperatures were about the same (52°). Upon arrival in Hong Kong, temperatures in the same positions were 59° for the dry ice pallet and 54° for the pallet without dry ice. A further increase occurred at the Hong Kong airport.

The third test shipment, sent to Tokyo, compared pallets with and without dry ice that were both shipped on an open, netted airline pallet (fig. 7). Upon departure from San Francisco, top layer temperatures of fruit in pallets with and without dry ice were 37° and 45° F, respectively (fig. 7). The temperature spread was maintained throughout the transit period and was 47° in the pallet with dry ice and 55° in the pallet without dry ice on arrival in Tokyo. Fruit temperature in the middle of the dry ice pallet averaged about 2° lower than that of the pallet without dry ice during transit.

Atmosphere Modification

The May test shipment to Hong Kong compared regular plastic covered pallets with pallets treated with CO_2 gas at shipping point. CO_2 concentrations in the treated pallets were 32 and 31 percent initially, 16 and 3 percent at San Francisco, and 10 and 0.5 percent at Hong Kong (table 1). Loss of the gas in these pallets was caused by tears in the plastic film. Some tears occurred at shipping point while shrinking the film around the load with hot air, and other tears were made while handling during transit.

The July shipment to Hong Kong compared pallets containing dry ice with pallets treated with CO_2 at shipping point. The CO_2 concentrations in the gas-treated pallets were 32 and 20 percent at shipping point, 12 and 11 at San Francisco, and 5 and 3 at Hong Kong (table 1). The CO_2 levels in the pallets with dry ice were 14 and 17 percent at San Francisco and 4 and 8 percent at Hong Kong (table 1). Tears in the plastic film again were responsible for the excessive gas leakage rate in all pallets.

TABLE 1.—*Carbon dioxide concentrations in film-covered pallets of strawberries shipped from California to the Far East*

Destination, date, treatment, and pallet number	Concentration of CO_2 at indicated points in transit		
	Initial	San Francisco airport	At destination
	Percent	*Percent*	*Percent*
Hong Kong shipment, May 1974:			
CO_2 gas No. 1 [1]	32	16	10.0
CO_2 gas No. 2	31	3	.5
Regular No. 1 [2]		0	.5
Regular No. 2		0	.5
Hong Kong shipment, July 1974:			
CO_2 gas No. 1	32	12	5.0
CO_2 gas No. 2	20	11	3.0
Dry ice No. 1 [3]		14	4.0
Dry ice No. 2		17	8.0
Tokyo shipment, August 1974:			
CO_2 gas No. 1	6	8	6.0
CO_2 gas No. 2	12	8	12.0
Dry ice No. 1		28	34.0
Dry ice No. 2		26	22.0
Regular No. 1		0	8.0
Regular No. 2		0	6.0

[1] Sealed pallets charged with CO_2 at shipping point.
[2] Pallets covered with shrink wrap plastic film.
[3] Pallets with dry ice above top layer and covered with shrink wrap plastic film.

The August test shipment to Tokyo compared all three types of plastic covered pallets (table 1). Special care was taken during this test to patch all holes in the plastic films at shipping point and at the San Francisco airport. The CO_2 concentrations in the gas-treated pallets were 6 and 12 percent at shipping point, 8 percent in both pallets at San Francisco, and 6 and 12 percent at Tokyo. The dry ice pallets had 28 and 26 percent CO_2 at San Francisco and 34 and 22 percent at Tokyo. The regular atmosphere pallets had accumulated 8 and 6 percent CO_2, as a result of respiration by the fruit, upon arrival in Tokyo.

Decay

The percentage of decayed berries varied widely in all strawberry shipments but was usually higher in top layers than in middle layers of fruit in the same pallet (table 2). Fruit temperature was the dominant factor affecting decay during transit. The only two pallets in which decay was higher in the middle layer than the top layer were the dry ice pallets sent to Tokyo (table 2). In these pallets, the top layer temperatures remained lower through most of the transit period than the middle layer temperatures. The same two pallets, which were the only pallets to maintain concentrations of CO_2 above 20 percent for most of the transit period, were the lowest in overall decay.

Soft and Overripe Fruit

The number of soft, overripe berries did not differ greatly among the three types of pallet shipped. However, fruit in the top layers usually

TABLE 2.—*Effect of atmosphere and temperature on the decay and softening of California strawberries shipped to Hong Kong and Japan*

Destination, date, and treatment	CO_2 on arrival	Temperature of indicated layer at examination		Decay of fruit from indicated layer		Soft, overripe fruit from indicated layer	
		Top	Middle	Top	Middle	Top	Middle
Hong Kong shipment, May 21, 1974:	*Percent*	*°F*	*°F*	*Percent*	*Percent*	*Percent*	*Percent*
CO_2 gas: [1]							
Pallet 1	10.0	75	58	5.1	0.0	64.5	5.4
Pallet 2	.5	75	57	10.5	1.4	72.4	26.1
Regular: [2]							
Pallet 1	-----	75	59	7.0	1.0	24.7	9.9
Pallet 2	.5	75	58	5.0	0	87.5	5.1
Hong Kong shipment, July 9, 1974:							
CO_2 gas: [1]							
Pallet 1	5.0	66	46	6.0	4.5	7.0	6.8
Pallet 2	3.0	66	46	14.1	3.6	7.7	3.6
Dry ice: [3]							
Pallet 1	4.5	72	57	3.5	2.3	2.7	3.4
Pallet 2	8.5	72	56	10.8	3.6	3.6	3.6
Tokyo shipment, August 27, 1974:							
CO_2 gas: [1]							
Pallet 1	6.0	55	45	5.3	4.2	10.6	5.0
Pallet 2	12.0	-------	-------	1.9	1.6	7.6	4.0
Dry ice: [2]							
Pallet 1	34.0	47	43	0	4.2	9.7	6.7
Pallet 2	22.0	-------	-------	1.8	2.7	9.1	5.4
Regular: [3]							
Pallet 1	8.0	53	44	9.9	3.3	8.1	10.7
Pallet 2	6.0	-------	-------	5.5	-------	4.6	-------

[1] Sealed pallets charged with CO_2 at shipping point.

[2] Pallets covered with shrink-wrap plastic film.

[3] Pallets with dry ice above top layer and covered with shrink-wrap plastic film.

were softer and riper than fruit in middle layers (table 2). This difference was particularly noticeable in the first shipment to Hong Kong (table 2). Top layer temperatures were higher during transit on this test than on subsequent tests.

CONCLUSIONS

Temperature was the overriding factor affecting decay and ripening of strawberries during transit. Handling and shipping procedures that help retain the initial low temperature achieved by precooling should be used whenever possible. These tests showed that a closed airline container, such as the LD–3 or LD–7, helped to slow warming of the fruit. Placing dry ice on top of the pallet also slowed warming of the fruit, especially in top layers. When used in combination with a closed container, dry ice should provide the most protection; however, adequate insulation to prevent freezing must be provided.

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